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ORDINARY MEETING,

Held at the Free Library, William Brown Street, Monday, November 3rd, 1890, the President in the Chair.

NOMINATIONS.—Mr. W. Roberts, of 5, Melrose Road, Kirkdale; Mr. McFall, of Stoneycroft; Mr. Pritchard, of 201, Bedford Road, Bootle.

The President, D. Clague, F.G.S., gave an Address upon

"THE SCOPE OF GEOLOGICAL STUDY."

The key-note of this Address will be found in the opinions sometimes expressed, that Geology is a *dry, uninteresting and profitless study*. I hope to be able to give to such adverse criticism an effective answer.

The scope of geological study, as usually explained to elementary students, is threefold: (1) a study of the composition and character of the rocks; (2) the history of these rocks from their very beginning, noting all the changes which they have undergone, and the various forces, mechanical or chemical, which have altered and modified them; and (3) the life-history of the earth—tracing the succession of animals and plants that have flourished on the earth from the earliest ages to the present, and noting the habits and foods of these various organisms.

Here is clearly no narrow or restricted study, if to the extended field we add, according to the rules of our Association, "its allied sciences;" and this is perfectly legitimate, for he would be a sorry geologist who had no acquaintance

with the sciences which treat in detail the various forces which produce geological effects. It will, then, be manifest that a geologist is not a person of small attainments or limited vision, and it would be passing strange if in so wide a field all tastes were not gratified, and every student find congenial mental food.

I propose in this address enumerating a few of the very numerous heads under which our studies may be arranged.

CHEMISTRY.—The chemical changes which take place in the rocks are a study of surpassing interest, and calls out all the chemical knowledge we possess. What can be more interesting than to trace the gradual change which takes place in the Felspars, when the alkaline elements which they contain combine with carbonic acid, forming soluble compounds, which are speedily removed in solution; whilst *Kaolin*, the hydrated silicate of alumina, is left behind for awhile, until it, too, is washed out and carried away to form mudbanks at some distant river's mouth, hills of hardened shale, or, it may be, slate quarries ready to be utilised by the builder?

Or, again, consider the changes which are going on in the Basalts, which contain many cavities caused by various gases having been imprisoned there during the cooling of the lava; in the course of ages a rearrangement of the molecules takes place in the surrounding matrix, some of these pass into the cavities and combining there to form exquisite clusters of Zeolite Crystals (specimens exhibited).

Other changes deserving attention are those which Iron passes through on being exposed to varied influences. Take, for instance, the common yellow Pyrites. On exposure to atmospheric agencies the Iron in the Pyrites parts with the sulphuric acid with which it had been combined, and takes up oxygen and water, forming the still more common *hydrous oxide* of iron; the sulphuric acid thus set free is ready to combine with any

matter for which it has an affinity, notably Limestone (Carbonate of Lime), which it converts into Gypsum. An interesting example of this action is to be seen on the Filey coast, where a mass of the dark clay is to be found containing a great quantity of Pyrites; on taking up oxygen the Pyrites is converted into the Brown stain which marks the clay in bands, when it is washed out by rain and streams of water; the liberated sulphuric acid at once attacks the fossils present, decomposing the surface and covering each with clusters of beautiful Selenite crystals.

CRYSTALLOGRAPHY is a branch of our study which is at present engaging a considerable amount of attention, not only for the beauty of those natural geometrical forms, but also for the fact that by means of a study of Crystallography we are enabled to ascertain the approximate composition of minerals.

It is well known that each mineral crystallizes in some definite form, still there are some difficulties before us in this study. Calcite and Aragonite, for instance, are minerals of similar composition, yet they crystallize not only in different forms but in different systems. Calcite, again, has forms innumerable, passing by insensible degrees into the form of a kindred mineral, Dolomite. Now the question whether these various forms are not due to some small amount of impurity present in the mineral is one worthy the attention of chemical Geologists: it is, in fact, engaging their attention, and it is quite possible that when their work is completed we may be enabled, from the measurement of the angles of a crystal, to read as from a book its chemical composition.

The DISTRIBUTION OF THE ROCKS, as depicted by the colours on a geological map, may have a far-reaching import beyond the thoughts of many. It is an excellent exercise for a young geologist to take up his geological map and, with the little knowledge he may have gained in a single course of lessons in one of our science classes, to picture to himself the various

features of a given district. Here, he sees the rugged grandeur of the Palæozoic rocks hardened and crumpled with many intrusions of igneous matter; there, the undulating downs of a great expanse of homogeneous rock worn down by chemical denudation; or the gentle slopes of a sandstone formation.

Let him consider how the climate, and consequently the health of the inhabitants, must be affected by the foundation rocks—damp and foggy amid the fens of Norfolk, giving rise to racking rheumatism; or dry, healthy and bracing when the underlying rocks are porous sandstones. Health and disease depend more upon geological conditions than many people think. One of my earliest recollections of Liverpool is connected with the removal of an acquaintance from a comfortable home, under the doctor's orders—because the house, being built on clay (our well-known boulder clay), was unfavourable to his health—to one less commodious, but which was situated on more elevated land; and in addition to the expensive sewerage carried out by the Municipal authorities, he had the advantage of the natural drainage afforded by porous sandstone rock. In many districts complaints are common amongst the inhabitants which are not known elsewhere; for instance, the peculiar swelling of the glands of the neck known as Goitre, which is common in mountainous mining districts, where the principal rock is Limestone.

Here is abundant scope for the Hygienic Geologist.

THE ECONOMIC ASPECTS OF GEOLOGY are both interesting and profitable, some rocks producing building stones of choice qualities, whilst others are quite unfitted for such a purpose. Some rocks yield immense quantities of mineral matter, which is a source of wealth not only to the district in which they are found, but also to the whole nation.

On this part of the subject there is little need for my saying more on the present occasion, for on the importance of the question I suppose all are agreed—though, unfortunately,

all persons concerned in the matter have not the requisite knowledge to distinguish the valuable from the worthless. Only recently a box of Felstones and Basalts were submitted to me as specimens of choice marble *from a quarry to be purchased and worked at the expense of a company of shareholders.*

THE PURSUIT OF AGRICULTURE is one very intimately connected with the study of Geology, although it is often overlooked, as it seems a far-fetched idea to connect cabbages and turnips, wheat and oats, with geological study; but they are most intimately related—the very soil in which these roots and cereals grow has been produced by the disintegration of the underlying rock, or is an alluvium brought down by rivers from the disintegrated rocks of some inland county. The very soil has a definite geological character which is too much overlooked, and according to this character it is sandy or clayey, loamy or peaty, and consequently fitted to grow some crops luxuriantly, whilst others would prove complete failures. Hence the character of the crops grown, and in consequence the kind of stock kept on the farm; and the kind of cultivation that must be pursued to make farming profitable depends upon the geology of the district, and calls for special study of men who may be termed *Agricultural Geologists.*

Dr. Buckland graphically describes the meeting together of three travellers who are supposed to have traversed our country in three different directions, and in comparing their observations, one expressed an opinion that Britain was a thinly peopled, sterile region, whose principal inhabitants were miners and mountaineers; the second came to the conclusion that the British people were a manufacturing people, raising and using great quantities of coal, building immense cities and carrying on many manufactories; the third would describe the conntry and people as purely agricultural. "These dissimilar conditions of the three great divisions of our country result from a difference of the geological structure of the respective districts." ("Bridgewater Treatise," introduction, page 1).

Perhaps I may be regarded as a dreamer in saying that the MENTAL CHARACTER OF OUR PEOPLE and the LITERARY WORK OF OUR AUTHORS IS LARGELY INFLUENCED BY THE GEOLOGICAL FEATURES OF THE COUNTRY IN WHICH THEY RESIDE. Move amongst the common people, listen to their fireside stories, join in their festive songs, study them—each district has its own type of story and of song; true, there is much in common, love tales with humorous or tragic endings are common everywhere, because they are true to human nature; spectres and sprites and fairies may be common to all, for men everywhere feel after the spirit world, but the character of these imaginary beings vary with each district. Amid the rugged grandeur and sublimity of our mountain gorges the songs and tales of the people have a ruggedness, a freshness, a sparkling vitality not to be found in the equally natural but tamer tales of the lowlands and the marshes.

Can anyone imagine Sir Walter Scott's splendid, rugged romances having been written amid the palaces or the slums of London? How incongruous would be the spirit which pervades "Peveril of the Peak" or "The Antiquary" amid the shops of the Strand or the clubs of Piccadilly! No; London cannot produce a Scott, but it can produce a Dickens, who, in stories equally true, tells of London dens in diction appropriate to his theme which could not have come to him amid Scottish moors.

Whatever exceptions there may be, the rule is that poets breathe the mountain air and have their spirits filled with the poetry and the music which whistle around the crags and surge along the valleys; the mountaineers think in poetry and speak in tropes of nature's teaching, whilst the inhabitants of low and level lands give rise to the mathematician and the prosaic, matter-of-fact, stolid man of business.

The MICROSCOPE is now an important factor in the study of Geology. By its aid we can read the internal structure of the

SAN FRANCISCO.

rocks and learn their history as without it we never could have done; by its aid we learn the relation of the Glasse Obsidian to the coarsest Felstone Porphyry; by its aid we learn which, amongst the minerals of our Crystalline rocks, first crystallised into form; by its aid we can detect the first signs of decomposition, and trace the various changes which rocks and minerals undergo in their various transformations. Perhaps, however, the interest felt in these questions is for a moment eclipsed by recent investigations in other directions. Mr. Wethered, F.G.S., has been examining the structure of Oolitic rocks, and has discovered that they are not all of chemical origin, as has been supposed, but are organic in their character and origin, and consist of aggregations of tubules of tiny creatures named Girvanella. ("Quarterly Journal of the Geological Society.")

Another deeply interesting discovery made by means of the microscope is described by M. Muntz, of Paris, who has discovered "nitrifying micro-organisms very abundant even on the bare rocks of mountain peaks," and he attributes to them a considerable share in the breaking down of rock masses into soil. ("Nature," vol. 42, p. 263). Thus adding one more to the organic agents of denudation with which we have to deal.

Palæontology is a branch of geology which presents to us a wide field of study. True, fossil hunting is not geology, for a part cannot contain the whole; the converse, however, is equally true, that the whole includes the part, and geology includes fossil hunting and fossil studying.

Here the biologist comes to our aid, and as he tells of monads and protoplasm, describing the habits, motions, character and mode of reproduction of the lowliest animal existencies, the geologist collects the shells which in ages long past were secreted by, and formed the tiny skeleton houses of, some of those housed monads, the foraminifera. As he leads

us up to the higher branches of his study and introduces us in turn to the conchologist and the zoologist, who talk learnedly about the habits and manners of all kinds of beasts, both great and small, we find ourselves quite at home with these learned men, rejoice in the information they impart to us, and in turn we can tell them facts and supply them with illustrations which we have gathered from our rock studies which will make their systems more complete; and by this knowledge, which thus is increased by the union of the observations of the votaries of various sciences, we learn to read between the lines much of the habits, food, loves and fights of the creatures of the past whose fragmentary remains are imbedded in the rocks; and the rocks, which otherwise were vast charnel houses full of dead bones, become quickened into life and activity. The dry bones live; dead and dry they may be physically, but a little knowledge of the phenomena of the life of the present day clothes these dry bones with muscles and sinews and skin and flesh, and causes them to parade before the enlightened imagination an exceeding great army of living creatures.

The same thoughts are true in relation to plant life also; we come across many relics of a past vegetation, and ask the botanist to help us; readily he assents, and as he speaks of cellular structure, fibro-vascilar bundles, and the multitude of parts that constitute a plant, we find their very counterpart amongst the contents of old rocks, and this binds the geologist and the botanist in the bonds of a common brotherhood of study.

When we consider these things we learn something about the unity of the world—past and present meet together. Many changes have taken place; there have been upheavals and subsidences, cataclysms have rent the rocks, epidemics have destroyed animals, and forests have been drowned by floods in all past ages; but when we find in Cambrian rocks a Lingula, in Ordovician rocks a Rhynchonella, and Terebratula

in the rocks of carboniferous age, then turning to the cabinets of the curious we find shells of the same character, which were collected only a few months ago with the living animals in them. When we examine the Lias rocks, and come across the stems and branches of the Pentacrinus Briareus, and then look at the Pentacrinus Maclearanus gathered alive by Sir W. Thompson, we are made to feel that the past and the present are bound together in one great whole.

Nor is this impression weakened when we turn to the plants; it was rather strengthened when standing amongst the refuse thrown out of a coalpit—every bit of stone crowded with broken stems of *Calamites*, and between the stones of this rubbish heap there was growing a profusion of the common *Mare's Tails*—the past and the present met together, the old and the new. What a study for a painter!

In Mesozoic and Cainozoic rocks we find leaves of a plant which were described by the late Professor McNab as like immense maidenhair ferns, but which really belong to a much higher form of vegetation; these he called Salisburia. In the rocks of our coal measures we have a plant possessing similar characters, known as Noeggerathia. A similar plant, the only one known, is still found living in the grounds of the Temples in China, where it is cultivated by the priests and called Ginkgo; here again the past and the present meet and shake hands. So let geologists and botanists, and zoologists and conchologists, and biologists and agriculturalists, and quarrymen and colliers, and mineralogists and chemists—aye, and even poets and painters, be united in the common search after knowledge; and since all these sciences and arts unite in ministering to our information, amusement and profit in the grand study of geology, let no man say that it is a narrow, uninteresting, or profitless study.

ORDINARY MEETING,

Held at the Free Library, William Brown Street, on Monday, December 1st, 1890. The President (Mr. D. Clague, F.G.S.) in the chair.

ELECTION TO MEMBERSHIP.—Mr. R. W. B. Roberts, of 5, Melrose Road, Bootle; Mr. S. McFall, of Bankfield Road, Stoneycroft; Mr. A. R. Pritchard, of 201, Bedford Road, Bootle, were elected Members.

A Paper was read on

THE RELATION OF GEOLOGY TO AGRICULTURE.

BY W. SCOTT WALKER.

No occupation is so closely connected with geological conditions as that of the Agriculturist, unless it be that of the Miner; but the latter's touch with geology is limited compared with that of the former, as many formations yield no profit to the Miner, while the Agriculturist deals with soils formed from the whole series of rocks, igneous, metamorphic and aqueous.

The soil is the raw material from which the farmer extracts products for food and clothing. Soils vary much in character. They are very complex bodies, containing both organic and inorganic matter, but by far the greater bulk is formed of inorganic substances derived from the decay of rocks.

When a soil is formed from the rock on which it rests, it is termed "local" or "sedentary," but when formed from the detritus of other rocks it is termed "transported." Alluvial soils and boulder clay are examples of those termed "transported."

Local soils are of much the same character as the underlying rock. Thus, sandy soils are found on sandstone rocks, clay soils on clay rocks, calcareous soils on limestone rocks, and so on with each bed.

"Transported" soils generally bear no relation to the underlying rock, in fact, they are often quite different, as when clay is seen resting on gravel, sand on clay, or bad clay on good.

In ordinary fields we find four different layers of material. First, we have the fine earthy matter called *Soil*, which is cultivated for the crop, containing more or less organic matter; under this we have *Subsoil*, in which there is organic matter and more stones; below this again is a layer called *Brash* or *Ravine*, consisting chiefly of rocky fragments of the foundation rock; while the fourth and lowest layer is the *Rock* from which the upper material has been chiefly formed.

Most of our soils might be classed as either arcenaceous, argillaceous, calcareous, loamy, or peaty. The rental value of a farm is to a large extent fixed by the soil, but the sandy soils of one formation may be barren, and those of another exceedingly fertile. The same fact holds good with regard to clayey, limey, and other kinds; it is, therefore, necessary to know on what bed the farm is situated, as the Geological formation has more to do with the fertility than the class of soil. Three of the highest rented counties in England are chiefly on the Trias, whilst the lowest rented are on the chalk.

All the most important items of farm management are influenced by the geological formation on which the farm rests. In draining, for instance, the method chosen is according to the nature of the soil and subsoil. If the soil is sandy, probably it may be drained by boring through the retentive substratum; if clayey, and underlaid with clay, by a system of pipe tiles; if clayey, but underlaid by gravel, a system (known as Elkington's), which is a combination of boring—Artesian Well fashion—and ditches or pipes might be employed; if

peaty, a plan known as "wedge" draining, (the wedges being made of the peat itself) would be adopted.

The class of farming is also influenced. We find the Silurian, Carboniferous and the Chalk under grass; the London Clay and the Lias under the plough; the Oolite and the New Red Marl are adapted for dairying; the New Red Sandstone for mixed husbandry, and so on, each formation having a characteristic class of farming.

The live stock is very different on one set of beds to another. On the Silurian we find mountain cattle and sheep, on the Old Red Sandstones and the Chalk we have many lowland breeds, such as the Hereford cattle and the Down sheep.

The water supply on the Chalk being very deficient, and on the Trias very plentiful, we find sheep which do not require to drink water in this climate, on the Chalk, and cattle which always require water on the Trias.

The supply of mineral manures, such as Lime, Marl, Gypsum, &c., is very important, for on some lands they are indispensible. Peat, for instance, will not yield a profitable crop until it has been dressed with clay and lime in some form.

The cropping and kind of crops are also different on each formation. This is well illustrated in Messrs. Johnstone's and Cameron's "Elements of Agriculture, Chemistry, and Geology," by a section from the Atlantic to the Alleghany Mountains. Near the sea we find low swampy alluvial flats, very rich, yielding large crops of rice, "sea island cotton," and trees of the type of the swamp willow and the cypress. Further inland the ground rises, and is firmer and drier; tobacco, sugar and maize flourish; the trees are oak and hickory. Next we come to tertiary sands, with dismal swamps, sandy wastes, thin pine forests, and very little cultivation; then follows treeless prairies on the chalk marl, with deficient water supply, and their soil yielding "flinty"

corn and Alabama cotton. In this last district we find coloured labour. Passing on, we come to clays and loams of various qualities on igneous and metamorphic rocks, where forests of broad-leaved trees abound and general husbandry is carried on by white settlers—the facts clearly shewing the intimate relation existing between geology and agriculture.

LIVERPOOL GEOLOGICAL ASSOCIATION,

FREE LIBRARY, WILLIAM BROWN STREET, LIVERPOOL

Established 3rd June, 1880.

Council 1890-91.

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SOIREE.

On Monday, January 5th, 1891, the meeting of the Association took the form of a Soiree. During the earlier part of the evening the members had the opportunity of cultivating acquaintance with each other, and informally discussing the various questions affecting the welfare of the Association.

A choice collection of geological photographs was on exhibition, lent by Messrs. O. W. Jeffs, J. H. Jones, I. E. George and D. Clague.

A visit was then made to the Free Public Library and Museum, where Mr. P. Cowell, Librarian, had made special arrangements for an inspection of the choicest specimens of geological literature contained in the Library, and Mr. T. J. Moore, C.M.Z.S., afforded facilities for special study in the Museum.

On reaching the Museum the company broke up into three parties—one, conducted by Mr. C. F. Webb, D.D.S., inspected the cases containing the collection of stone implements; Mr. C. M. Coffee conducted a second party round the Stone Gallery; and a third party accompanied the President to the Phillips Collection of Minerals.

At eight o'clock a lecture was delivered in the Museum by Mr. D. Clague, F.G.S., on "Ancient Dragons." This lecture, being one of the course of Monday evening lectures organised by the Museum Sub-Committee, was open to the public, who attended in considerable numbers, and manifested much interest in the geological matters brought before them.

At the close of the lecture the company adjourned to the Lecture Hall, where the chair was occupied by Mr. A. Norman Tate, F.I.C., F.G.S., &c., past President, and an excellent selection of music was rendered by a string band, under the able leadership of Mr. F. W. Stubbs.

NOMINATIONS.—During the meeting the following gentlemen were nominated for membership:—Messrs. J. Paterson, 18, Normanby Street; R. Storey, Imperial Chambers; J. Hanley, J.P., of Garston; and G. A. Haworth, of Waterloo.

ORDINARY MEETING,

Held in the Free Library, Monday, February 2nd, 1891, Mr. D. Clague, F.G.S., President, in the Chair.

Election.—Messrs. J. Paterson, R. Storey, G. A. Haworth and J. Hanley were elected to membership.

Exhibits. —Native gold, silver and copper, and several other minerals, were exhibited by Mr. J. Brown; some chalk fossils, by Mr. J. Herbert Jones; and a collection of South Carolina fossils, including tooth of the mastodon and several reptilian remains, by the President.

A Paper was then read on

THE INFLUENCE OF GEOLOGICAL FORMATION UPON SHORE FAUNA,

By James Hornell.

[Abstract].

A common axiom of Biological Science is that every animal is suited directly to its surroundings, or environment: that is to say, amidst particular surroundings a certain animal is seen at its best, at its highest development. Here it attains the greatest individual size, and the community of which it forms a unit is usually large in numbers.

This agreement between animal and environment has come about in a very gradual way. Whenever individuals arose differing a little from the parent stock, in a way in sympathy with the character of the locality they inhabited, these more favored individuals would be more likely to attain to maturity and live longer than representatives of the normal type. Thus, they would possess a greater chance of producing offspring larger in numbers and better developed than those of the latter. The young bred from this better variety would in turn exhibit frequently the good points of their parents, and thus the deviation which was at first an unstable variation would tend to become permanent.

To show how such an operation is conducted by Nature, by a case in point noted by a highly esteemed friend of mine—Mr. J. Sinel, of Jersey. In this named island great masses of Syenite occur, and the bottom of many rock pools in sheltered localities is composed of very coarse black and white sand, or rather shingle, the *debris* of the surrounding Syenite. In these pools the common shrimp (*Crangon vulgaris*) is often found, but be it noted that though in anatomical detail the body is identical with the structure of the shrimp found everywhere in our seas, the colouring is conspicuously different. Instead of the numerous minute grey-yellow dottings so characteristic of ordinary individuals, the body is emphatically dappled black and white, resembling wonderfully closely the coarse black and white syenite shingle of the bottom of the pool.

There can be no doubt that the dappled variety has sprung from the ordinary type species by the greater chance of escape from enemies which individuals varying a little in the direction of dappling would possess over the normal.

It may be objected that amongst the millions of shrimps seen in the shallows round this locality such abnormal colouring is never observed; but be it remembered that in this purely yellow sand district such markings would entail destruction long before maturity, because of their great conspicuousness.

Variation is far from being of rare occurrence: indeed, it is one of the commonest facts in Nature. What is comparatively rare is for the variation to be of practical benefit to the animal possessing it, for it to occur in a number of instances simultaneously, and thus to possess the necessary essentials for being perpetuated.

The bearing of our science on the phenomena of adaptation is exceedingly intimate. It is the geological formation—the kind of surface rock—that determines in greatest measure the facies of the earth, and hence is the chief controlling factor in the life of every region.

The maximum of this geological influence upon the development of life—upon the formation of new species and varieties from pre-existing forms—is attained on that part of the shore comprised between tide-marks. It is here that the surface rock has to bear the greatest brunt of the waves' attack. Every weak spot is searched out; caves and crags, sands and mud-flats, boulder and shingle beaches appear. The result is that this—the "littoral zone"—is, where hard rocks crop out, the most diverse, the least uniform region of the earth. Great variety of situations are created, suitable to very different inhabitants.

The diverse characters assumed by the littoral divide themselves naturally into two well-marked and distinct categories, according to the degree of hardness of the rocks exposed to marine denudation.

On the one side is an infinity of variety of rocky shores, formed by the breaking up of hard, compact rock; on the other are the monotonous and even-featured sandy and muddy shores, derived in great part from the disintegration of soft strata.

Rock dwellers, as a class, are in the main characterized by greater activity—leading free, wandering lives; with more brilliant and vivid colouring and infinitely greater diversity of form than their sand or mud-dwelling congeners. Devices assumed for protective or mimetic purposes are also more varied and ingenious.

Activity.—A good instance of the activity engendered by life in rock haunts is the lithe, supple eel. The great number of its vertebræ, with their exquisite jointing, gives it the necessary pliability for winding rapidly in and out among boulders, while the smoothness of the skin reduces friction to a minimum. A large proportion of the annelids exhibit in equal degree this extreme of activity, *e.g.*, *Eulalia viridis* and *Nereis pelagica*.

Vivid colouring, while common among rock animals, has usually other than a geological bearing, and cannot be dealt with here.

However, the colouring of the rocks and boulders of the shore has no inconsiderable influence upon certain creatures, tending to produce in them dull and inconspicuous markings. Professor Herdman recently noted an interesting instance illustrative both of this fact and of the allied one that such mimetic animals endeavour to increase the resemblance to the motionless stone by shamming death when surprised. The animal he mentions is the small flat-clawed crab (*Porcellana platycheles*), so very abundant under boulders of carboniferous limestone at Puffin Island. The dirty greyish-brown colour of the carapace simulates exactly the muddy surface of the decaying rock.

Limestone rock, from its liability to chemical corrosion and the frequent inclusion of fossil remains of varying hardness, presents generally a much more uneven surface than sandstone or schist. In this way it offers greater opportunities for hiding, and many animals are, for this reason, found almost solely on limestone shores. The little green Phyllodocean worm, *Eulalia viridis*, is a case in point. At Puffin Island it swarms, and also on the neighbouring Limestone mainland. On the sandstone Hilbre Island I have never found it. *Eulalia* is of a brilliant green colour, and would be immediately picked up by its enemies from the brown rock were this rock not full of little natural and artificial (*Saxicava* bored) cavities, into which the worm can scurry on approach of danger. Hilbre presents smooth rock surfaces generally, without any of these little refuges; hence, absence of this worm.

Just a few points about our sand fauna.

Such is influenced far more widely by the surrounding geological factors than rocky shore faunas. This is due to

the absence of complicating outside influences, such as the presence of seaweeds for instance, and to the absolute similarity of one particular environment over very extensive and unbroken tracts.

All sand animals share more or less in certain peculiarities. The two chief of these are burrowing habits and the assumption of markings closely resembling the general dull yellowish colour of the sand itself.

Representatives of so diverse an assemblage as molluscs, echinoderms, crustaceans, worms and fishes, are all in varying degree endowed with one or other of these—often with very curious modifications, and even with additional adaptations to the peculiar geological condition of their home.

Sand mollusca, sand worms, and sand echinoderms are all burrowers; their colour has little or no reference directly to their surroundings. Absence of pigment and non-predaceous habit of life are their chief characteristics.

With sand fishes and crustaceans burrowing is seldom more than superficial—the scratching and flinging up of a tiny cloud of sand with the aim that this shall descend in a shower on the creature's back and so mask its presence from its foes or its prey.

But the concealment thus mechanically afforded is partial, and is greatly aided by the mimetic sand markings assumed by nearly all of these animals on the parts usually exposed. Soles, flukes, rays, shrimps, and the curious burrowing crab *Corystes cassivelaunus* at once suggest themselves.

It may be noted that the fishes add a third to the above-mentioned efforts after concealment, viz., extreme flattening and thinning of their bodies so as to bring the shape into complete harmony with the surrounding featureless sand plains.

ORDINARY MEETING,

Held at the Free Library on Monday, 2nd March, 1891. The President (Mr. D. Clague, F.G.S.) in the chair.

ELECTION.—Mr. W. L. Atkinson was elected a member.

A paper was then read on

THE WORK OF A RIVER.

BY MRS. S. SCOTT.

[ABSTRACT.]

The work of a river may be studied in two ways: (1) In the *Geological* sense as a denuding and transporting agent. (2) In a *Commercial* and *Hygienic* sense—furthering trade, supplying water to towns and villages on its banks, and acting as a scavenger to the whole district through which it passes.

It is in the first sense I wish to speak of a river this evening, and shall briefly trace the river from the "little drops of water" to the "mighty ocean."

All are familiar with the fact that evaporation is carried on chiefly from the waters of the ocean by the great agent, the *Sun*; clouds are formed which in turn disgorge their contents in genial showers. Every shower of rain in the open country washes something off the surface of the land, and carries it away in muddy runnels to the nearest stream, and thence to the riverside. Not only so, but so soon as the rain-drops reach the ground they begin to dissolve some portion of the earth's crust, and thus carry off what they can in solution, and push forwards and downwards whatever they have power to move. When these streams and rivulets unite in some mighty river the operations carried on are essentially the same as in the tiniest rill, but are colossal in magnitude compared with those of the rain-drops with which we started. The Geological work of a river then may be divided into two, and studied in its *Mechanical* and in its *Chemical* aspects.

'Weak as water' is a common saying, yet water is the agent which destroys whole continents and carries them away to the ocean, and rebuilds them there into new continents. The material of which the world is composed is continually changing places.

It often happens that stones of considerable size are loosened from the cliffs, tumble into the stream, get worn and fretted by the particles of sand washing over them, until they become rounded; some greater flood sets them in motion, they get broken up, get rolled over and over till they are worn again into boulders and pebbles; a continuation of this destructive work breaks them up still smaller, till they are known as gravel and sand. This material rolled along deepens and widens the bed of the river, and so secures new material to be carried onwards.

If a river has a steep bed, it has a great carrying power. Mountain torrents, for instance, rush down steep slopes, and not only transport vast quantities of gravel, sand and mud, but often move stones of considerable size. Floods, too, increase the denuding force of rivers, for we read of floods sweeping away bridges, tearing up rocks, and carrying stones weighing several tons.

The amount of excavation which can be wrought by means of running waters has been noticed in volcanic regions where rivers have cut through sheets of lava which have been poured forth at known dates. The grandest results of river action, however, are seen in the immense chasms through which some of the rivers of Colorado flow, the streams at the bottom being hemmed in by vertical walls, which, in some places, are a mile in depth. Probably these Canons owe the preservation of their vertical sides to the fact that the country is comparatively a rainless one. If the rocks over which the river flows are soft and easily eroded, the river bed is soon cut down, and the neighbouring valley widened by the action of the weather; where the rocks are relatively hard and compact, the river

channel is cut narrow and deep, and the water tumbles over rapids and water-falls. We have abundant illustrations of these features in British rivers; for instance, the rapids of the Clyde, near Lanark, and the deep gorge of the Spey, as contrasted with the soft flowing Avon, or the gently moving broad valleyed Thames.

The material carried away from mountain top and hill side finds a lodging place in the lake or sea in which the river empties itself. A striking example of this is seen in the lake of Geneva, through which the river Rhone passes; it enters the upper end of the lake as a turbid stream laden with detritus brought down from the Alps, but at the lower end of the lake it issues as a rushing stream of the most translucent water purged of its impurities, which are deposited in the lake, so gradually filling it up. It sometimes happens that without flowing into a lake, a river may be relieved of its sedimentary matter by overflowing the adjacent lands in time of flood, forming alluvial meadows which are so common along the banks of the Thames. Another noted instance of alluvial land having been formed by river floods is the case of Egypt, where the overflow of the Nile has produced an immense Delta. The Delta of the Mississippi is another instance; it consists of an enormous tract of swampy ground in the Gulf of Mexico, furrowed by numerous streams, estimated to have an area of 12,300 square miles, and which is advancing seawards at the rate of more than 200 feet every year.

In some estuaries the tidal current is so charged with muddy water that it is utilised by the inhabitants by being artificially carried over the low-lying lands which it covers, with a fine silt called *warp*. This is done in the estuary of the Humber.

The amount of solid matter suspended in river water and so carried seawards varies considerably in different rivers. With regard to the Thames, it has been estimated that it discharges annually 1,865,903 cubic feet of sediment. The

mass of material carried in suspension by the Ganges would form every year a column one mile square and 225 feet high.

In addition to all this, much matter is carried away in solution, shewing as the result, vast caves in limestone districts with all their accessories of Stalactites and Stalagmites, tufa beds and rugged gorges; and adding to the sea great quantities of solid matter in a state of solution.

Thus the sea receives the contents of all the rivers from the land, the sun again evaporates the water and forms fresh clouds, the clouds again break into rain, pouring their contents into the rivers, the rivers again work their way steadily to the sea, and thus the everlasting round goes on.

The paper was illustrated by a series of fine views of river scenery, shewn by the optical lantern.

FIELD MEETING, EASTER MONDAY.

This was held at Flaybrick Hill, and was conducted by Dr. C. Ricketts, F.G.S. The principal features studied were the evidences of glacial action, which are here well exhibited. At the N.E. corner a compact fine-grained bed of rock has been quarried, the section of which can now be seen shewing the junction with the overlying boulder clay as a sharply-defined straight line. The surface of this bed before it was quarried, and after the boulder clay had been removed, was seen to be beautifully polished and striated by the action of moving ice. The same ice action seems to have varied its effects in different localities according to the nature of the material dealt with. At the opposite S.E. corner, where the rock is coarse-grained and incoherent, the surface is broken up instead of being smoothed, and a thin bed of pipeclay is seen to lie between it and the boulder clay. This bed of pipeclay, Dr. Ricketts pointed out, was probably derived from the denudation of a bed containing numerous clay pebbles—a section of which is to be seen in another part of the quarry—the derived clay and sand being spread out as a thin bed by the moving ice, and forced into fissures and hollows of the surface of the rock.

ORDINARY MEETING,

Held at the Free Library on Monday, 6th April, 1891. The President (Mr. D. Clague, F.G.S.) in the chair.

EXHIBITS :—A specimen of Wilhelmite (Anhydrous Silicate of Zinc) was exhibited by Mr. A. R. Pritchard, which he had obtained from the Boulder Clay of the neighbourhood.

Mr. W. H. Miles gave a report of the Field Meeting held at Flaybrick Hill on Easter Monday, an abstract of which appears on the preceding page.

A paper was then read by Mr. J. Herbert Jones on

THE ECONOMIC ASPECTS OF THE GEOLOGY OF CAITHNESS,

Illustrated with diagrams, maps, and numerous rock specimens and fossils.

ABSTRACT.

There is a prevailing opinion that the district with which this paper deals is one of the most uninviting portions of the British Islands, and is devoid of every feature of interest; but, although to the tourist from the South the county has somewhat of an uninviting aspect on account of its want of trees and of its general flatness, it is full of interest to the student of natural history and antiquities, and to the geologist its bareness is rather an advantage than a drawback, as the contour of the ground can be clearly observed in all its detail.

In order to show how absolutely necessary it has been for the inhabitants to utilise to their fullest extent its natural productions, a few general particulars of the county may be given.

Little more than 100 years ago not a single cart road existed, and there was not a cart with wheels in the county.

The telegraph was not introduced until the year 1868, and no railway existed before 1874. Very rapid progress has, however, recently been made, as is shown by the facts that there are now 300 miles of excellent roads in the county, and that between the years 1831 and 1881, whilst the population increased by only 2000, viz:—from 36,500 to 38,500, the valuation increased from £35,000 to over £158,000.

It is to the applications of those natural productions, of interest to the geologist, that the following remarks will chiefly be confined.

The County of Caithness is situated almost wholly upon the Old Red Sandstone formation, the rocks of which are supposed to have been laid down in vast freshwater lakes, penetrated, probably, here and there by an arm of the sea.

The line of hills which forms the Western boundary of the County, consist principally of crystalline rocks and Gneiss, such as generally prevail in the adjoining County of Sutherland, and give to it its rugged character. Upon these lie the rocks of the Old Red system, consisting of:—

(1) A coarse conglomerate of granitic breccia largely composed of pebbles and fragments of orthoclase felspar, grit and fine-grained sandstones—evidently derived from the same materials. The conglomerate proper is of little economic value; but the freestone with which it is associated is highly suited for building purposes, as blocks of any required size are obtainable, and it becomes harder by exposure to the atmosphere.

(2) An enormous mass of red and yellowish sandstones, dark-coloured bituminous flagstones and limestones. This portion of the formation is of the greatest commercial value, as within its range are found the well-known Caithness flagstones, so largely used as a street pavement; and it is also the most interesting to the geologist on account of its fossil contents.

It occupies almost the entire area of the central plain, in every part of which quarries have been opened out, though it is chiefly from those in the vicinity of the town of Thurso that the material is obtaine for other than local uses.

The pavement trade has long been an important one in this county. Fifty years ago the quarries and works of Thurso employed 250 workmen, and those at Castletown 100, and from this latter place alone over 300,000 sq. feet of flag were shipped every year. Recently, however, reverses have overtaken the trade, owing chiefly to the introduction of artificial pavement.

The quarries at Thurso are situated three miles inland from the town, at a height of about 250 feet above Ordnance datum. In them the best flagstones here obtained lie at a depth of about 30 feet from the surface. The dip of the beds is very slight, and the face of the quarry almost perpendicular. The tools used to separate and raise the flags from its bed are few and simple. They consist chiefly of wedges to open out the joints and divide the folds, heavy crowbars to move the material about, and hammers to dress it into shape. Masses of flag weighing from one to three tons are frequently raised and split up afterwards with wedges into almost any desired thickness. A tramway conveys the trucks to the works adjoining the Thurso harbour, and the flags are here sawn and polished by steam machinery as may be required for foot-walks, kerbs, crossings, mantelpieces, shelves and a variety of other uses.

The flagstones also furnish a roofing material, smaller in size and much thicker than Welsh or English slates. Flags of inferior quality are used as a fencing material, and have the advantage of being easily erected and removed. They are placed about 1 ft. in the ground and 3 ft. above, and provide an ample fence against cattle. Flagstone is also used for dyke building, gate posts or pillars, drains, cisterns and many

other purposes: it is also quarried for road metal, for which some kinds are highly suited. The colour of the flag is an indication of its quality—that of a deep purple hue being the best.

The Sandstones of this division provide a very good building stone.

The Limestones furnish a lime highly suited for agricultural and building purposes, though I am not aware that they are worked to any considerable extent in the county.

As regards the scenery of this flagstone area:—Inland, as has been observed, it is persistently flat; but, as Dr. A. Geikie, in his "Scenery of Scotland," says—"This singular tameness is fully compensated by the boldness of its coast scenery." * * * "The Old Red Sandstone forms round the margin of the county an almost unbroken line of mural precipice. Its two dominant structures, bedding and jointing, manifest their influence everywhere in the character of these cliffs. The strata, for the most part gently inclined, consist of thin alternations of different varieties of flagstone, some of which withstand the weather better than others. The faces of the precipices are consequently etched out in alternate lines of cornice and frieze. By means of the vertical joints the rocks are split into clean perpendicular faces, which repeat themselves along the main cliff on each inlet or goe and on every buttress and isolated rock." * * * "Nowhere in Britain can these features be so impressibly seen as along the great ranges of Old Red Sandstone coast cliffs of Caithness and the Orkney Islands."

The fossil contents of this portion of the formation consist chiefly of the remains of fishes.

According to the recent classification of Mr. Smith Woodward, which has received the approval of so high an authority as Dr. R. H. Traquair, these belong to the sub-

classes *Elasmobranchii*, *Ostracodermi*, *Dipnoi*, and *Teleostomi*. In the first of these have been placed the Acanthodians—the chief characteristic of which is a strong spine placed in front of each of the fins, except the caudal or tail fins. The body is covered with minute ganoid scales, and the internal skeleton is cartilaginous.

The OSTRACODERMI includes those whose bodies were covered with large bony plates, and amongst which are the earliest known fishes.

To the DIPNOI belong those forms which are allied to the mud fishes of the present time. In addition to their gills they possessed an air bladder connected with the gullet, and which, acting as a lung, enabled them to breath upon land as well as in water. The tail in some was of the diphycercal form, and in others it was heterocercal. The scales which covered the body were imbricated, and hooked together in a similar way to that in which tiles are fastened to each other upon a roof.

The TELEOSTOMI includes the remainder of those forms generally classed as Ganoids, and to which the most common of the Caithness fishes belong. In these, the internal skeleton is cartilaginous, the aperture of the gills is covered externally by an operculum; the rays of the paired fins in many of the species are ranged around a scale covered lobe, the ventral fins are invariably placed near the hinder part of the body, the head is covered with bony plates coated with enamel and the body with scales of similar structure, arranged in diagonal rows. Most, if not all of the specimens exhibited, belong to this sub-class.

The remains of Crustacea are also found in this division of the formation, as also are fragments of land plants.

(3) The uppermost beds of the system consist of yellow and red sandstones and mottled marls. They occur only on

the two promontories of Dunnet and Duncansbay heads, and owe their appearance here to faults.

At Dunnet they produce an excellent building stone, which has been largely used in many of the principal buildings of the county.

Dunnet Head is one of the most impressive pieces of the scenery of this coast, rising perpendicularly from the sea to a height of 346 feet.

Boulder clay of two very distinct kinds overspreads the county in irregular patches, that which occupies the N.W. portion being of a grey colour, containing boulders of secondary rocks and marine shells, whilst that which lies along the base of the higher grounds is of a reddish brown colour, its contained boulders &c., being exclusively of local rocks.

From a minute examination of the various glacial phenomena of the county, recently made by Messrs. Peach and Horne of the Geological survey, it has been concluded that the grey clay is the produce of the united Scandinavian and Scotch ice sheets, which passed across the county in a N.W. direction, and that the red clay is the produce of the local glaciers.

Glaciation has done much to vary the scenery. On the West side of Thurso Bay the cliffs of grey clay, over 100 feet in height, are a striking feature; being very similar in form to our own boulder clay cliffs of Cheshire, as seen on the banks of the rivers Mersey and Dee.

Boulders from the clay are largely used in the construction of dykes, and, when broken, afford a good metal for roads, as do also the gravels with which the deposit is associated.

The clays are chiefly employed as a substitute for mortar. No brick or tile works exist in the county, and brick buildings are unknown.

Peat is obtained in all low-lying parts; it is the only fuel readily obtainable. It is cut for use in the month of May, and left on the moor to dry for 3 or 4 months, when it is carted home. Peat differs much in colour and quality, the former being a certain indication of the latter—that of a yellow or light brown colour being the worst, and that of a dark brown or black the best, providing a fuel very slightly inferior to coal.

Stone was largely employed by the most remote inhabitants of those parts of whom we have any knowledge. Dr. Joseph Anderson, in his account of "Scotland in Pagan Times" and "Scotland in Early Christian Times," fully describes the investigations which have been made in Caithness into the cairns and other remains which are so abundant in the northern and eastern portions of the county, and in which he gives some highly interesting details of the ancient employment of those materials which now so largely occupy the attention of geologists.

APPEAL TO THE MEMBERS.

That the Association does not belong to a small party of officers and their friends but to the membership at large is a truth which cannot be too much insisted upon. All the members are interested in its work and welfare, and all are called upon to manifest that interest:—

(1) By as frequent an attendance at the meetings as possible, and by taking an active part in them by a free expression of opinion on the various questions brought forward; by exhibiting fossils, minerals, rock specimens, photographs, drawings, sections, &c., and communicating to their fellow members information about any exposures of rock sections which may have come under their notice, and which it may be desirable to visit.

(2) Members who, through business engagements or residing at a distance, may render valuable service by occasional communications giving particulars of the geological features of the districts in which they reside, accompanied, when practicable, with sketch maps and sections; and also by communicating to us the substance of any geological study or work in which they may be engaged. These notes from various parts of the country would be invaluable helps to fellow members studying in districts of a very diverse character, and so each member would profit by the labours of all.

(3) As the holiday season approaches, it would be well for our members, in fixing on their place of recreation, to study beforehand from books and in conversation with their fellow members the geological character of the district they intend to visit; when there, work out these characters on the spot for themselves, and on their return give us the benefit of their studies and observations in the form of communications, to be read at the meetings of the members.

(4) Every member can render efficient aid by a *prompt* payment of the annual subscription. It would be light work for each member to remit the amount to the Treasurer; but it would be heavy work for him to have to hunt up each member and solicit payment. In this simple manner, therefore, let each one do something to lighten the work of the officers.

(5) Members may manifest their interest in the work of the Association by bringing their friends as visitors to the meetings, whether held indoors or in the field, and to which they will be made welcome; also by inducing their friends to become members with us.

In these varied ways, amongst others, every member may do something to make our Association successful, remembering that "*many hands make light work.*" C.

ORDINARY MEETING,

Held at the Free Library, William Brown Street, Monday, 4th May, 1891. Mr. I. E. George, Vice-President, in the chair.

EXHIBITS.—A selection of Fluor Spar and Mountain Limestone fossils were on the table to illustrate the paper of the evening.

A paper was read, of which the following is an

ABSTRACT.

NOTES MADE ON A VISIT TO CASTLETON.

By CECIL F. WEBB, L.D.S., D.D.S.

The walk from Miller's-dale to Castleton is one which possesses many attractions for the geologist. Passing into Miller's-dale, we enter the lower thickly-bedded Limestone. In places the valley contracts into narrow gorges, with sides rising direct from the river Wye in vertical cliffs. At one spot we observe two exposures of toadstone—one above the other. Wherever met with, much interest always attaches to the observation of these ancient lavas; and these two layers, with the great masses of shelly-limestone above and below them, cannot but offer interesting suggestions as to successive sub-marine volcanic outbursts. It may also be noticed that, in some places, instead of presenting the appearance of shapeless, massive, intrusive rock, it is found in the form of irregular spheroids, varying in size from small ones at Miller's-dale to the larger rounded but somewhat twisted forms found near Buxton.

These are interesting—not only from their resemblance to some of the forms thrown out by modern volcanoes, but as indicating the violence with which the molten rock was

ejected through the spaces left by the disruption of the strata, and became twisted, as shot becomes mis-shapen from the friction and force with which it is shot from the barrel of a gun.

A few miles from Miller's-dale we enter the town of Tideswell—at one time a place of considerable importance, having been the central market town of the lead-mining district of Derbyshire; but, with the decay of the lead-mining industries there, the town has lost much of its former importance.

A walk of some 7 or 8 miles, up hill and down dale, through mountain limestone and millstone grit, brings us to the village of Castleton—immortalised by Sir Walter Scott in his "Peveril of the Peak." The village lies in a dale immediately at the foot of "Old Mam Tor," or, the "shivering mountain,"—one of the highest mountains of the peak, rising to an altitude of more than 2,000 feet above the level of the sea. The soft shales which compose it are readily decomposed by atmospheric agency, and, crumbling into small fragments, which slide down the steep side of the mountain, give rise to the popular name it bears.

The dip of the beds is about 40° E.N.E. They can be traced through Hope to Hathersage. A good section is exposed also along a brook below Mam Tor, where the shales are seen resting against the lower limestones.

The castle of Castleton is one of the most interesting and curious Norman fortresses in existence. The roofs and portion of the walls are still standing, and worthy of the most careful consideration. The masonry is of the most massive character, and the details of pure Norman work, including some herring-bone masonry, are among the most valuable examples at present extant. The situation of the fortress is commanding in the extreme, and, in the height of its glory, the Castle of

the Peak must have been one of the most impregnable strongholds in the kingdom. The view from these ruins is extensive, fine, and varied; indeed, the whole district supplies such a number and variety of splendid views that the traveller wishes for a longer stay.

Close to the village of Castleton is the great Peak Cavern, the most remarkable of all the Derbyshire caverns—in fact, it is one of the finest in the country. It extends some 2,250 feet into the mountain, and is about 600 feet below its summit. It is reached by following a pathway along the side of a clear rivulet which flows through a chasm between two tall cliffs; a turn in the road leads us to a natural arch, 42 feet high and 114 feet in width. This imposing hall of entrance is 300 feet long. After proceeding along this hall for about 30 yards, the visitors enter the first of a series of smaller caves—the roof becoming lower and the passage narrower till at length it becomes a narrow slit in the rock, and all trace of daylight is lost; candles are lighted, and the first great cave is reached; another 30 yards' walk along a narrow passage brings us to the chamber called the "Bell House," which is almost surrounded with water, and approached by an artificial bridge; the water is not, usually, more than 3 feet deep. Next, walking along the side of a subterranean river (named the "Styx") for some distance, the "Great Cave" is at length reached—a magnificent cave, 270 feet long, 210 feet broad and 12 feet high. This is the largest cave in England, and is seen to great advantage when lit up with Bengal lights. The next visit is to "Roger Rain's House," where the water is always falling, and supplies the stream which flows out of the cavern into the river Derwent. Another cavern, 1,100 yards from the entrance, called the Victoria Cavern, has not long been discovered.

Scarcely a mile from Castleton is another of the wonders usually explored by the geologist as well as the ordinary

sightseer—the Speedwell Mine. This is an artificial opening excavated in search of lead by a company of proprietors who expended £14,000 and spent 11 years in the work, and then gave it up as a fruitless task. This level is about half-a-mile in length, and opens into one of the most remarkable natural gulphs ever discovered. By the assistance of candles and Bengal lights an attempt is made to view the lofty cavern spread above, but in vain the visitor tries to penetrate the deep gloom which fills the abyss, while the stream, rushing along and plunging into unknown depths, made the very rock on which we stood tremble.

The immensity of this chasm may be imagined when it is remembered that over 40,000 tons of rubbish have been thrown into it without having to any appreciable extent restricted its capacity, whilst into the space overhead rockets have been thrown to a height of 450 feet, at which height they have burst and thrown off beautiful coruscations as freely as in the open vault of heaven.

One of the prettiest sights in Castleton is the Blue John Mine, situated in a hill called Trecliffe. It is about 600 feet in height, the dip of the rock is about 25° N.N.E.

"Blue John" is a local name for the mineral known as Fluor (fluoride of calcium). Few mines in the world produce such splendid specimens of this mineral as does this one. It is found in "*pipe veins*" which have the same inclination as have the rocks which the veins traverse. One of these veins lies on a clayey stratum, and another consists of crystalline nodules of Fluor imbedded in a mass of indurated limestone *debris*. In addition to these *pipes* of Fluor, the sides of the cave are faced with the beautiful violet cubes of Fluor, intermingled with rhombohedral crystals of calcite.

The entrance to this cave is effected by passing down a series of steep steps, and when a light is placed in proper

position the eye is pleased with the beautiful play of light reflected from the facets of the spar with which the cavern is adorned.

A large chamber, fully 150 feet in height, called "Lord Mulgrave's Dining-room," is next reached, and after that the "Variegated Cavern." In order to give visitors any adequate idea of this place, the owners have fixed a chandelier on pulleys, which, when the candles are lighted, is gradually elevated so as to illumine the place and shew the beautiful stalactites and crystals mingled in admirable confusion. The lights, however, fail entirely to pierce all the recesses; and the gloom beyond, which the eye fails to reach, raises in the mind a feeling of profound awe.

On the Castleton road is an old mine, called the Odin Mine, worked at one time by our Saxon forefathers, which produced galena that yielded upwards of 3 oz. of silver to the ton of ore.

The remarkable fissures which occur in the Limestones of Derbyshire have afforded matter of speculation to the curious for centuries. Such a fissure is to be seen at the back of the village, and goes by the name of the Cave Dale. Some good work may be done in the lower beds, almost every stroke of the hammer opening out some new fossil treasure. Trilobites have been taken out quite perfect. Groups of Cytherœa and Cyclas radialis, a rare fossil, and quite a bed of Pleurorhynchus armatus is to be seen. These last, however, are very fragile, and require great care in extracting them to preserve the cones entire.

Plutonic action has not been absent from this neighbourhood, for at the upper end of the dale are beds of greenstone which are columnar in structure, like the Antrim basalts--the columns which are exposed being about 3 feet high and 1 foot wide, whilst the Limestones adjoining have been crystallised

by the heat to which they had been subjected by the intrusion of igneous matter.

That most remarkable fissure called the "Winnats" is about a mile from Castleton. The name, originally Wind Gates, has, no doubt, been applied to this place on account of the fierce howling of the winter's wind down the ravine. The scenery is sublime—it looks as if a hill had been split in twain, and the precipices on either hand, for the distance of a mile and a-half, resemble the ruins of some ancient fortress, with the old towers and buttresses still remaining, covered in places with ivy and tenanted with owls and bats. Much speculation has arisen as to the origin of these ravines and caves; but to the geologist they tell of one of the most powerful, though quiet, forces which are at work in the world—wearing down the hardest rocks, eating into the heart of the mountains and carrying away the solid earth, invisible it may be, but none the less really, to the sea: I mean "CHEMICAL DENUDATION."

FIELD MEETING,

Held at Matlock Bath on Whit Monday, conducted by the President. Soon after arriving at Matlock, attention was directed to the blocks of tufa, which had been brought from the bed of the river where it had been chemically formed by the deposition of the Carbonate of Lime with which the waters are impregnated. After this, the party visited and explored the "Cumberland Cavern," where, in addition to the fact that it owed its existence to chemical denudation, small veins of Toadstone and numerous stalactites and minerals were the interesting features observed.

Subsequently the High Tor was visited—there a considerable fault is exposed, and many patches of slickenside with horizontal striæ, were examined; familiar limestone fossils were collected, and attention was drawn to the characteristic flora of the Limestone district.

ORDINARY MEETING,

Held at the Free Library on Monday, 1st June, 1891. The President (Mr. D. Clague, F.G.S.) in the chair.

EXHIBITS:—A collection of animal remains, including horses' and rhinoceros' teeth, portions of stags' horns, &c., taken from the cave earth of a recently opened cave at Little Ormeshead—was exhibited by Mr. R. Storey.

Mr. R. H. Ashley gave a report of the Whit Monday Holiday excursion, (see preceding report.)

A paper was then read by Mr. Jos. Davies on

THE DIAMOND.

ABSTRACT.

It is not at all surprising that a body of the great beauty and rarity of the diamond should have for ages been eagerly sought after, especially when it is considered that it, as well as other precious stones, were supposed to be possessed of a spiritual as well as a material potency; such, for instance, as the curing of disease, averting calamity, &c., a power still ascribed to them by the inhabitants of some of the mountainous parts of Spain and Arabia. The natives of India regard the gem as a preservative against lightning, and imagine that when taken into the mouth in the form of powder it will make the teeth fall out.

Reviewing briefly some of the quaint and absurd notions of the ancients—circumscribed to a great extent by reason of their idea that the invincible "adamas" was in some occult manner related to the much-prized king of metals—regarding its composition, mode of formation, &c. Pliny says of the diamond that "it seemeth that it should grow nowhere but in gold." He also ridicules Metrodorus Scepsius' idea about this gem being found in a locality "wherein amber is engendered," but this idea, from the modern chemical standpoint, is more sound than the old philosopher's own notion that

"diamonds breed not but in mines of gold." Plato describes it as a kind of "kernel" formed in gold, affirming also that it was the noblest and purest part of the metal that had condensed to a transparent mass. The Greeks stated that it did not become warm when subjected to the action of heat, and also that it was incapable of being broken by means of a hammer, this latter fallacy being confirmed by both Lucretius and Pliny.

Jerome Cardan, born in 1501, in his "De Subtilitate" lays down the dictum that the "diamond, emerald, and opal are engendered by juices that distil from gold in the cavities of rocks." Subsequently in the 17th century Boyle was the first to notice that under the influence of great heat it disappeared. Newton seems to have made a pretty shrewd guess at, or rather about its real composition, for comparing it with other bodies that possess the power of refracting light in a very high degree, he states that it may probably prove to be combustible, or as he again describes it, "an unctuous substance coagulated."

A series of rapid strides in the direction of determining its real composition soon placed this latter beyond a doubt, the experiments of Lavoisier in 1772 and the masterly researches of M. M. Dumas and Stas upon the equivalent of carbon at once indicating its identity from a chemical point of view—with the other allotrophic modifications of that element.

The Diamond consists essentially of carbon, but perfectly pure diamonds are very rare. The diamonds burnt by Dumas and Stas in the experiments previously referred to, gave a residue of ash varying from $\frac{1}{500}$ to $\frac{1}{2000}$ of the weight of the original diamond taken. This ash upon examination gave indications of the presence of Silica and Peroxide of Iron, but the quantity being so small nothing very definite could be absolutely stated.

The diamond exists in nature in three forms: crystallised, crystalline and amorphous. It usually crystallises in modified octahedral forms, having the faces curved or rounded; which gives to the crystal an almost spherical figure. The first or crystallised form is the one cut and worn as an article of jewellery. The second or crystalline form, unlike the previous one, cannot be cut, so is reduced to powder and used for grinding and polishing purposes. It is known in commerce as "boart," many of the stones being smoky in appearance and frequently almost black. The third or amorphous form is steel grey in colour, and usually found in sandstone of very old formation, in Bahia and lately in Mexico. It is known to jewellers as the "carbonado" or "carbonic diamond."

The average specific gravity of the diamond is 3·5, and, as its name implies, it is the hardest substance known. It is a non-conductor of electricity. It is absolutely infusible when subjected to ordinary treatment; but heated between the terminals of a powerful battery (with exclusion of air) it swells up and is finally converted into a mass of coke or graphite.

If free access of air be permitted, it is completely converted into carbonic anhydride. By a modification in the manner of performing this last experiment, it is found by arresting the combustion that the stone burns in layers, the system of crystallization being always regularly displayed. This is of considerable importance as it precludes all idea of fusion for the diamond.

Exposed for some time to daylight and then removed to a dark room, the diamond exhibits the phenomenon of phosphorescence, which is, however, not at all permanent, disappearing in the course of a few days. This phosphorescence in the diamond is destroyed by heat, but is again rendered visible by an electric discharge.

A microscopical examination of the native crystallised gem reveals the presence of a number of minute cavities—first pointed out by Sir David Brewster—which usually contain liquid.

Most stones, when cut and polished, present a very beautiful appearance on account of the very faint tinge of colour which they usually possess. This, in some of the most highly valued gems, is often of a pale rose tint, but is oftener yellow; whilst in the commoner forms it sometimes assumes a decided brown or even black appearance. Bearing upon the commercial value of a gem in this respect, the stone presented to the French Academy of Sciences some hundred years ago furnishes us with an interesting example. The diamond in question was a comparatively small one, weighing only 4 grammes, and was normally of a brownish shade; but, subjected to a very strong heat for a couple of hours, the brown shade completely disappeared and gave place to one of the finest rose tints imaginable. In this condition its value was said to be from 150,000 to 200,000 francs; whereas in its normal condition 60,000 would certainly have been the limit of its value. It was also stated that after continuing in the rose-tinted condition for a period of some 8 or 9 days, it reverted to its original shade. This experiment was repeated five or six times, the same change in colour and the same reversion taking place each time.

Following up the observation of these physical properties of the diamond—properties so widely different to those exhibited by the other allotropic forms of the same elementary body—chemists are led to the belief that this dissimilarity is due to a difference in their molecular structure. An investigation of the specific heats of these three varieties confirms this view, and affords grounds for the belief that the diamond molecule consists of four atoms, the graphite molecule of three atoms, and the charcoal molecule of two atoms of carbon.

Considering the mode of occurrence of the diamond, one cannot help being struck by its comparative scarcity. This is, however, probably explicable on the supposition that the "finding" of a stone in any particular locality is dependent upon the *condition* more than upon the *abundance* of the igneous rocks.

The true geological position of the diamond is unknown; but it is always found in the dèbris of the igneous rocks. It has been stated that in one instance—and this an unsubstantiated one—in 1827, a diamond was found embedded in a fine-grained quartzose rock (Itacolumite) in Brazil.

Previous to the Christian era diamonds were exclusively obtained from Ethiopia; but when Pliny wrote (about 0-55 A.D.) they were already being brought from India, and till the 18th century none were known but these Indian gems.

The Golconda mines were visited in the 17th century by Tavernier, a French jeweller, who gave some interesting particulars regarding them and the methods adopted by the natives for obtaining and disposing of the stones, which latter are here found in conglomerate sandstone.

In the 18th century diamonds were found in Brazil, and over 100 years afterwards in South Africa. About this time also, in accordance with a judgment expressed by Humboldt, they were found in the Ural Mountains; whilst recently they have been received, but only in isolated cases, from Sumatra, Java, South Carolina, Georgia, Alaska, Arizona, Mexico and Australia.

The Brazilian beds lie about eight feet below the surface of the soil in a conglomerate of rounded stones, under two distinct layers—the uppermost a mixture of sand, gravel and loam, and the other "thick black clay or mud."

In Africa the beds are situate to the N.E. of the Orange River Free State, the country "here rising into long stony ridges, consisting of irregular fragments of hard rock embedded in ferruginous gravel, which varies in character and compactness, being sometimes quite loose and sometimes forming a compact lime-cemented mass." The diamondiferous alluvial gravel consists of nodules of granite, sandstone, basalt, greenstone, agate, garnets, garnet spinels and peridot, with here and there, but at rare intervals, the princely gem itself. The alluvial soil lies in some instances above the calcareous tufa, and in other places above the basalt, and in many parts above a clayey shale of various colours.

Regarding the formation of the diamond very little can be definitely stated, although it seems pretty certain that it has been deposited from solution—two statements previously set forth giving great force to this conclusion.

The first of these is its regular crystallization in layers—a peculiarity noticed only in connection with crystals which have been deposited from solution, and the second the presence of the liquid in Sir David Brewster's cavities, which is analagous to the small quantity of water always retained by some crystals after deposition from solution, and which causes them to decrepitate more or less violently when heated. Sir David Brewster was of opinion that diamonds had been produced in some direct manner from organic matter, but this view seems hardly tenable.

When attempting to mimic nature in the production of the diamond, we are confronted at the outset not only by the unchangeable solidity of carbon, but also by the absence of any solvent by means of which it can be brought into the liquid forms by the process of solution.

The first attempts at the fabrication of the diamond were

those of MM. Deville and Voehler, who also experimented upon the physical isomers of Carbon, Boron and Silicon.

Following upon these experimenters were Cagniard de Latour and Gannal—the former presenting his results to the Academy of Sciences on October 10th, 1828, and Gannal on November 23rd of the same year.

M. D'Espretez, in a series of experiments, succeeded in obtaining a black as well as a crystalline powder hard enough to polish the ruby; and M. Gaudin's report upon their action in this respect leads us to the conclusion that he was here dealing with veritable diamond dust.

Passing over the speculations of Chancourtois and the confessedly premature announcement of Mr. James Mactear, of the St. Rollox Chemical Works at Glasgow, we come to the results of Mr. J. Ballantine Hannay, who, experimenting upon the critical points of various gases, made the discovery that a liquid was not the only menstruum which was capable of holding a solid in solution. Following up these researches, he succeeded in preparing a crystallised adamantoid form of carbon—comparable, if not identical, with the diamond—and which Professor Maskelyne found would scratch deep grooves in a sapphire, as well as showing distinct traces of octahedral cleavage. The specific gravity was also about 3·5.

The chemical tests were also very satisfactory, the crystals giving a percentage of 97·85 of carbon.

Dr. Percy, lecturing on chemical geology in 1864, said on the subject of the artificial production of the diamond:—"We are so sanguine about this matter that we cannot refrain from believing that one day or other the thing must be done. *It assuredly will be done.* We have, apparently, been very near it from time to time, but have never yet reached it."

ORDINARY MEETING,

Held at the Free Library on Monday, 6th July, 1891. The President (Mr. D. Clague, F.G.S.) in the chair.

Mr. C. E. Miles gave a report of the Field Meeting held at Dawpool on June 27, when the threefold division of the glacial deposits were studied, the interglacial sands being there exposed very clearly.

The President reported a visit which, in company with the Secretary, he had made to the cave deposits recently exposed at Little Ormeshead. The visit proved to be of such an interesting character that arrangements are being made for a Field Meeting of the Society being held there in August.

A paper was then read by Mr. J. R. Pritchard on

THE BOULDER CLAY OF THE NORTH-END OF LIVERPOOL.

The localities described are Linacre, Bootle Docks, Bedford Road Brickfields, and the Brick and Tile Works, Moor Hey, near Crosby.

Linacre.

Sections were exposed here during 1870, whilst making foundations for the Gas Works, and were described by Mr. Isaac Roberts in the Proceedings of the Liverpool Geological Society.

The following is a summary of the succession:—

Vegetable soil, 1½ feet; sand containing marsh plants and roots, 7 feet; Upper Boulder Clay, 15 feet; coarse yellow sand and gravel, containing a large number of Turritella communis, 2 feet; Lower Boulder Clay, 15 feet; coarse gravel in patches resting on Red Bunter Sandstone.

Of far greater interest at present are the heaps of boulders thrown on an adjoining brickfield, which have yielded several

unique specimens. One is a block of grey compact limestone, running through which are a large number of small round tubes, which have a decided metallic appearance. The material of which they are formed, although having such a metallic lustre, is undoubtedly calcite. It has been suggested that they are the product of a burrowing annelid. Another specimen is an ammonite –probably derived from the Liassic rocks of Antrim—similar fragments having been found at Blackpool. The next is a loose buff-coloured limestone, containing one or two shell casts, which have not yet been identified. From its lithological character it has been referred to the Tertiary period. Among the igneous rocks, one is particularly prominent. Under the microscope it appears to be composed of a felsitic matrix, containing small crystals of plagioclase felspar and hornblende, with mica and apatite as accessory minerals. A portion of the hornblende has segregated into small veins, which give the boulders a very banded appearance.

Although found here in such large numbers, I have not been able to find a single specimen at Dawpool.

Bootle Docks.

Whilst excavating for the docks, magnificent sections of the Boulder Clay were exposed, which have been described by Messrs Reade & Morton.

They have been covered for many years; but the material thrown out contains many interesting boulders. From one I obtained a tooth of an acrodus; another boulder consisted of Keuper marl, containing layers of Gypsum. Before the deposition of the Gypsum, however, a considerable number of salt crystals existed. These, in the course of time, were dissolved, and the cavities filled with sulphate of lime, which, in consequence, presents the appearance of having crystallised

in the Cubic system instead of the Monoclinic. Very good specimens of Gypsum in its three forms—selenite, alabaster and the fibrous variety—can be collected readily from any of the stone heaps. A very pretty piece of indurated shale was found, containing many casts of Lamellibranchs in iron pyrites.

Large numbers of flints are to be seen; but it is difficult to say from what horizon they have been derived. A rather peculiar igneous rock is one formed of a dull grey matrix, containing small felspar crystals and minute nests or pockets of Malachite.

Brickfields, Bedford Road.

The clay seems to lie in a depression in the Bunter Sandstone. Here and there are thin layers of sand; but they are not continuous like the middle sands, and there seems to be no indication whatever of the Lower Boulder Clay.

Boulders are far from numerous, as is usually the case with the upper clay. Shell fragments are very common; and after heavy rains large numbers of fragmentary Turritella, Cardium and Cyprina can be found. Besides these, there have been found portions of Pecten, Tellina, Natica, a Dentalium, and a few others not yet identified. An interesting question crops up here, viz., Why are the shells in such a fragmentary condition? One explanation is that they have been broken by grounding icebergs. This, however, does not seem to have been the cause, as the majority of the univalves are practically complete.

The best explanation seems to be that the commination has been caused by the action of tides and currents. This explains why the bivalves have suffered more than the univalves. Take for example a Cardium. When alive it would have a nearly spherical form, and could be rolled along the sea bottom without injury; but, on the death of the mollusc, the elastic ligament which forms the hinge would

contract, causing the valves to gape and finally separate. The shell having lost the strength derived from its rounded form would be easily broken when thrown against boulders and other shells, and in this manner be reduced to the fragmentary condition in which it is found. In the case of a univalve, such as a Turritella, the death of the animal would in no wise affect the strength of the shell, and in consequence the only damage it would suffer, as a rule, being breakage at the lip or apex of the shell.

Another matter of considerable interest on these fields is the development, near the top of the clay, of calcareous nodules of considerable size. In one instance I found the matter aggregated round a root which had penetrated some distance into the clay, showing clearly that the marsh plants are older than the nodules.

Brick and Tile Works, Moor Hey.

This is certainly the most interesting section to be found in the North-end. At the bottom of the pit we have blue Keuper marls dipping very gently to the south or south-east. Resting on these is a deposit, some three or four feet thick, of kneaded up blue marls, in which are to be found large blocks of local sandstones, distinctly striated and embedded at all angles. Besides these a few erratics have been found—one being a large decomposing greenstone about a foot in diameter; but so few are they that Mr. Mellard Reade, in describing this locality before the London Geological Society some years ago, stated most emphatically that no foreign erratics were to be found.

The sandstones mentioned above are of two kinds—the one a coarse-grained quartzose rock, the other a fine-grained micaceous sandstone. On a small slab of the fine-grained variety I found a rounded cast about ¾ of an inch by 4½ inches,

which is thought by some to be a reptilian coprolite, and by others the cast of a worm—some very similar being exhibited in the Liverpool Museum. On a block of the coarse-grained sandstone some impressions have been found, the origin of which is still more doubtful. The best suggestion made is that they have been aggregated round a plant stem, as in one case there is a longitudinal cavity near the middle. Another fact connected with these coarser sandstones is that they contain a large quantity of copper. Some of the blocks have quite a blueish appearance from the presence of Chalcanthite, the hydrated sulphate of copper, which can be readily tested by placing a small quantity on the tongue.

The working up of the blue marls is attributed by Mr. Reade to the action of a glacier coming from the North. But it has been well remarked that the former existence of a glacier on the low-lying ground between Liverpool and the Lake district is improbable, and that a glacier should force its way from Westmoreland over such flat country is certainly difficult to realize. The opinion held by Mr. Morton is, that it is the work of an iceberg; and the fact of the deposit not being found at the south-east corner of the pit adds considerable weight to this theory.

Overlying the broken marl there is about 10 feet of boulder clay, containing the usual shell fragments and erratics. Among the latter two very interesting specimens were found. The first a block of Wilhelmite, the anhydrous silicate of zinc, exhibited some time back, and the other a boulder of Hemimorphite, the hydrated silicate of zinc, both of which have in all probability been brought from Cumberland. A block of Hæmatite showing many striations has also been found. Two blocks of limestone found in this pit exhibit features not unusual in boulders of this material from the boulder clay. To the smaller specimen a serpula had attached itself and covered one of the striations. The other has a large number of holes drilled in by lithodomous shells.

At the south end of the pit is a bed of gravel from 12 to 18 inches thick, in which many shell fragments are to be found in a rather poor state of preservation. Above this bed is the vegetable soil, about 2 feet thick.

Towards the end of June we were given a very favourable opportunity for studying the denuding action of rain. Within twenty-four hours there was a fall of over two inches, and as it flowed over the ground carried along a large amount of material to lower levels. Small gullies were formed, land-slips occurred, and at Crosby the appearance of the pit was considerably altered. On nearly all inclined surfaces earth pillars were to be found supporting small stones or shell fragments. On a specimen exhibited, about two inches square, two of these pillars were to be seen; one about ¾ of an inch high carried a shell fragment, while the other, a little smaller, held a piece of sandstone.

For the last 20 or 30 years the Boulder clay has been a continual "bone of contention." It has been discussed by men engaged in nearly every branch of scientific work; still there are scarcely any two who entirely agree upon the matter. In the current number of the Geological Society's Journal facts are brought forward which, together with an alteration in the level of the land, are thought by some to be sufficient to account for the glaciation of North-west Europe, without having recourse to astronomical causes, as explained by Dr. Croll.

It was suggested some years back that a depression of the isthmus joining North and South America would cause the Equatorial Current to flow into the Pacific Ocean. The paper describing the Geology of Barbadoes, by Mr. Jukes-Browne and Professor Harrison, shows that a depression took place in Miocene times, and that elevation commenced early in the Pleistocene period; but whether this alteration of level would alter the course of the Gulf Stream is very doubtful indeed.

The amount of depression is stated to have been 2,000 feet. Now the major portion of Southern Mexico has an average height of over 2,000 feet. In the isthmus itself there are only two areas, when the high ground falls below 500 feet; and by far the greater portion, after a submergence of 2,000 feet, would still remain above water. Again, the Equatorial Current does not impinge on the west coast of the isthmus bordering the Caribbean Sea, but passes northwards into the Gulf of Mexico. Yet it is along this coast-line that the narrow channels would be opened into the Pacific; so that it seems very probable from these considerations that the depression of 2,000 feet would not be sufficient to allow the Equatorial Current to pass through. Supposing the current was diverted, it could not have produced the glaciation of the northern and southern hemispheres. Therefore it would seem more logical to attribute the peculiar conditions of the Pleistocene period to some other agency.

The various specimens named and described were on the table, and exhibited during the reading of the paper.

FIELD MEETING.

On Monday, Aug. 3rd, a Field Meeting was held at Little Ormeshead, conducted by Mr. R. Storey, who led the party first to the limestone quarries of Trwyn-y-fawch, where the character and appearance of caves eroded in limestone by chemical action were studied, and subsequently to Porth Dynewth, where the features of "sea caves" excavated by marine action were studied.

The limestone caves yielded a rich harvest of bones and teeth of the various animals which had inhabited them in byegone days.

ORDINARY MEETING,

Held at the Free Library, William Brown Street, on Monday, 7th September, 1891. The President (Mr. D. Clague, F.G.S.) in the Chair.

EXHIBITS.—Various mineral specimens, and fossils from Little Ormes Head, shown by Mr. T. R. Connell.

NOMINATION.—Mr. Thos. D. Roberts, 4, Bankfield Place.

Adjourned discussion on Mr. A. R. Pritchard's paper, was opened by the President, and replied to by the Author.

AUDITORS.—Messrs. A. R. Pritchard and R. W. B. Roberts were elected Auditors.

A paper was read on

THE CLIFF SECTIONS OF THE YORKSHIRE COAST.

BY MR. R. W. B. ROBERTS.

Illustrated by photographs and many fossil specimens.

ABSTRACT.

The cliffs of the Yorkshire coast have long been famous with geologists on account of the splendid sections which are there exposed of most of the formations from the White Chalk down to the Lower Lias inclusive. From Flamborough to Whitby the coast sections afford unusual facilities for the study of rocks of Mesozoic age. Taking the coast as a whole, the rocks dip to the south at an angle of 3 or 4 degrees. Consequently, starting from the White Chalk of Flamborough Head and working northwards, we pass in succession the outcrops of the Speeton Clay, Kimmeridge Clay, Coral Rag, Oxford Clay, Kelloway Rock, Cornbrash, Inferior Oolite, Upper and Middle Lias, until the Lower Lias appears at Robin Hood's Bay near Whitby. This sketch of the coast

sections is, however, only a generalised one, especially as regards the dip of the beds, for in several localities the regular sequence of the formations has been disturbed by faults which have tilted up some of the beds at a considerable angle.

Boulder Clay is found capping the Secondary rocks all along the coast, and in many places forming the entire cliffs. The three divisions of the Drift with which we are so familiar here, are also apparent in the Yorkshire Clay, and their general characters are very similar to those of the corresponding divisions in this district. The Lower Boulder Clay is characterised by the presence of large boulders of Shap Fell granite, one of which may be seen at Seamer Railway Station. The cliffs of Boulder Clay which extend from Speeton to Filey often present a peculiar buttress-like appearance, due to weathering. Perhaps the most singular feature of the Yorkshire Drift is the manner in which it clings to the coast line. Although in some of the coast cliffs it attains a thickness of over 100 feet, it thins out very rapidly towards the interior, so that at a distance of about two miles from the shore scarcely any trace of it is to be seen. This is the more remarkable, as it does not appear to have been caused by any inequality in the surface of the ground. If the thinning out had taken place against a slope there would have been nothing extraordinary in it, but such is not the case.

Starting from Flamborough Head, the first formation which attracts attention is the White Chalk, of which Flamborough Head itself is formed. It differs from the White Chalk of the south of England in being much harder and less fossiliferous. It is also remarkable that the flints in the Yorkshire Chalk occur in the lower part, and not in the upper as is usually the case. On the north side of Flamborough Head where the cliffs rise perpendicularly from the shore and reach a height of 300 or 400 feet, the chalk is seen to be violently contorted. This is attributed to Glacial action. Con-

tortions on a smaller scale are also noticeable in the Corallian beds of Filey Brigg. The Chalk pebbles on the shore often shew dendritic markings when broken. Near Speeton Cliffs, the White Chalk may be seen passing at its base into the Red Chalk, which is the only Yorkshire representative of the Gault. This Red Chalk is noted for the great profusion of small Belemnites, chiefly *Belemnites minimus*.

Flamborough Head furnishes us with a very good illustration of the way in which promontories are formed. The chalk of which it is composed being of a hard siliceous character, has been better able to withstand the force of the waves than the softer clay and alluvium on either side, the unequal rate of denudation resulting in the formation of a magnificent headland.

The Chalk is not seen north of Speeton, its place in the cliffs at this locality being taken by a mass of blue and black clays, to which collectively the name Speeton Clay is given. Although grouped together under this general term, these clays represent seven different horizons: Upper, Middle and Lower Neocomian, Portlandian, and Upper, Middle and Lower Kimmeridge, of which the Neocomian and Portlandian beds are not represented anywhere else in Yorkshire. Unfortunately, the sections at Speeton are extremely difficult to study, owing to the numerous landslips which have occurred at various times, and which often make it hard to say what is *in situ* and what is not.

The Upper Neocomian beds which are found on the north side of Speeton Gap, may be divided into three parts. The uppermost is a black clay about 60 feet thick, which can be easily recognised in the cliff by its dark colour. It contains nodules of pyrites, but no fossils beyond a few small Belemnites. Underlying this black clay is about 50 feet of dark blue clay, which also contains very few fossils. Below this again, is a very light blue clay, 30 feet thick, containing layers of large septaria, composed of argillaceous limestone

with thick septa of calcite. This is known as the "Cement Bed," owing to the septaria being used in the manufacture of hydraulic cement. In 1868, when Professor Judd published his Memoir on the Speeton Clay, extensive mining operations were carried on in the Cement Bed. These workings have, however, been discontinued for some years. When exposed, the light colour of this clay makes it readily distinguishable from the darker clays above and below.

The Middle Neocomian clays, which underly the Cement Bed, are 150 feet thick. The upper part consists of about 80 feet of dark blue clay, with very few fossils, beneath this, being 40 feet of similar clay, with more fossils. Characteristic fossils of this lower clay are, *Pecten cinctus*, *Exogyra sinuata*, and *Belemnites jaculum*. The lowest division is a dark blue clay containing regular layers of light brown nodules. *Belemnites jaculum* is very abundant, and also species of Ancyloceras. From the fact that the latter fossil here reaches its maximum of abundance, this bed has been termed the "Ancyloceras Bed."

The Lower Neocomian of Speeton comprises about 200 feet of dark blue clay, containing much pyrites. In these beds, Belmnites are extremely plentiful, especially *Belemnites lateralis*. They are found lying on the surface, or sticking out of the clay in great numbers, but are usually in a more or less fragmentary condition. A marked characteristic of this division of the Neocomian is the presence of much selenite. Many of the fossils are covered with crystals of selenite, in such a way as to suggest the origin of the latter. They have resulted from the oxidation of the iron pyrites which is present in greater or less quantity throughout the clay, the sulphuric acid liberated from the pyrites combining with the lime of the shells to form beautiful crystals.

Succeeding these Lower Neocomian clays in descending order are some beds, which upon palæontological evidence

have been correlated with the Portland limestone and sand. The highest is a band of phosphatic nodules, 5 inches thick, which is called "Coprolite Bed." Under this is a thin band of peaty clay, containing ichthyolites, which in turn is followed by dark coloured clay, containing the coronated Ammonites characteristic of the Portlandian.

At the end of Speeton cliffs, nearest to Filey, the Upper Kimmeridge Clay may be seen outcropping at the base of the cliffs. It is a finely laminated black shale, containing many crystals of selenite between the laminæ. It is crowded with fossils, particularly Ammonites; but, unfortunately, they are in a very bad state of preservation, the Ammonites, especially, being crushed beyond identification.

A little further on towards Filey, the Middle Kimmeridge is exposed, and consists chiefly of dark pyritous clays containing selenite. In some places the clay is seen to glisten with minute crystals of pyrites. Under the microscope these crystals are found to be chiefly tetrahedrons. The Lower Kimmeridge is only visible occasionally, after the beach has been bared by heavy storms.

At about a quarter of a mile north of Filey Spa the Coral Rag appears from beneath the overlying Drift, and is seen to dip to the south east at an angle of about 4 degrees. From this point northwards, the strata gradually rise, until the whole of the Middle Oolites are exposed in the splendid sections of Gristhorpe Bay.

The Corallino Oolite is well developed at Filey Brigg, and comprises the Upper Limestone, Middle Calcareous Grit, and Lower Limestone. The Upper Limestone is the only part to which the term Coral Rag can be appropriately applied, as corals are entirely absent from the other divisions. The Middle Calcareous Grit consists chiefly of sandstones with calcareous bands. These sandstones contain among other

fossils large numbers of Serpulæ. They can be frequently seen in nests standing out in relief on the surface of the softer sandstones. Small Pectens are also common.

The Lower Limestone is not seen south of Filey Brigg. It first appears as a thin band of oolitic limestone on the north side of the Brigg, and it increases in thickness northwards, about 30 feet of it being found in the Castle Cliff, Scarborough. Underlying this limestone is a considerable thickness of calcareous sandstones and grits. The uppermost beds of these, about 30 feet thick, which consist chiefly of spongy grits, are called the Passage Beds as they form the connecting link between the Lower Limestone above and the Lower Calcareous Grit below. The Passage Beds and Lower Calcareous Grit are grouped with the Corallian beds, although no corals are found in either. About the middle of the Passage Beds is a thin band of spongy grit, called the Rhynconella Bed, from the abundance of *Rhynconella Thurmanni*. The Lower Calcareous Grit is extremely hard and well able to resist the force of the waves. Its weathered surface is very irregular and uneven, but perhaps the most interesting results of weathering are the doggers. These are spherical ferruginous balls, which, being harder than the surrounding sandstone, stand out prominently on the weathered surface and look remarkably like cannon balls imbedded in the rock.

Proceeding along the coast northwards from Filey Brigg, the Oxford Clay is found rising from beneath the Lower Calcareous Grit—the whole of it, about 100 feet, being exposed in the cliffs at Gristhorpe Bay. Lithologically, it differs very much from its equivalent in the south of England; in fact, the name Oxford Clay, as applied to this formation, is rather a misnomer, as it is not a clay at all, but a sandy shale. It is very poor in fossils—what few there are being very badly preserved. It has, however, a magnificent appearance in the cliffs at Gristhorpe, sweeping round the

bay in a graceful curve, the effect of which is enhanced by alternating light and dark bands. Above the Oxford Clay in these cliffs the Corallian beds stand out in reef-like masses. The shore is strewn with enormous blocks of Coralline Oolite, which have fallen through lack of support, owing to the greater rapidity with which the softer shale beneath has been denuded away.

Beneath the Oxford Clay at Gristhorpe the Kelloway Rock is seen forming a well-marked terrace round the bay. It is a brownish ferruginous sandstone, fossiliferous near the top, and about 30 feet thick. It rapidly increases in thickness northwards, until about 75 feet of it is seen at Scarborough.

The Lower Oolites first put in an appearance at Gristhorpe, the Cornbrash outcropping underneath the Kelloway Rock. It includes 6 or 7 feet of clay and about 2 feet of limestone. It is not easy to trace, being much obscured by the talus of the Oxford Clay above. The fossils are mainly obtained from the limestone, which is very fossiliferous. They are somewhat difficult to extract, being closely compacted and rather friable.

At the western end of Gristhorpe Bay the uppermost beds of the Inferior Oolite appear, and reach a thickness of over 100 feet. The Inferior Oolite of Yorkshire, as a whole, is an estuarine deposit; but there are alternating marine bands. According to the Survey Memoir its total thickness amounts to over 300 feet. The sub-divisions are as follows:—Upper Estuarine Series, Grey Limestone, Middle Estuarine Series, Millepore Bed, Lower Estuarine Series, and, lowest of all, the Dogger (so called from the presence of great numbers of ferruginous doggers). All these divisions are exposed in the cliffs between Gristhorpe and Scarborough, with the exception of the Dogger, which only occurs north of Scarborough. The estuarine deposits consist of false-bedded sandstones and shales, full of carbonaceous markings, with occasional seams of coal, which are, however, too thin to be

worked with profit. From Cayton Bay to Scarborough the cliffs are entirely composed of Inferior Oolite and Boulder Clay.

At the Castle Cliff, Scarborough, a splendid section of the Middle Oolites is to be seen. The succession is as follows:—Soil, drift and rubble, 10 feet; Coral Oolite, 24 feet; Passage beds, 28 feet; Lower Calcareous Grit, 66 feet; Oxford Clay, 135 feet; Kelloway Rock, 8 feet: in all, about 271 feet. This cliff is really an outlier, being cut off from the mainland by two faults, the throw of which probably amounts to about 100 feet.

North of Scarborough the Inferior Oolites again crop out, a complete section of them being seen in the high cliffs at Blea Wyke, near Robin Hood's Bay. The total thickness there is over 600 feet, comprising:—Upper Estuarine Series, 40 feet; Grey Limestone, 100 feet; Middle Estuarine Series, 100 feet; Millepore bed, 8 feet; Lower Estuarine Series, 270 feet; Dogger, 90 feet.

Between Blea Wyke and the South Cheek of Robin Hood's Bay is the first exposure of Lias, which, from Robin Hood's Bay to Whitby, forms the entire cliffs, with the exception, of course, of the inevitable Boulder Clay.

The Upper Lias comprises the Alum Shale, Jet Rock and Grey Shale. The Alum Shale is first seen at Blea Wyke, and is 150 feet thick. It is a soft greyish shale, formerly much used for the manufacture of alum. This industry has, however, been extinct for some years, the alum being obtained from other sources. The characteristic Ammonites of this division are *Am. communis* and *bifrons*.

The Jet Rock is a dark-coloured shale, 25 feet in thickness, which is celebrated, as its name implies, for being the chief source from which the Whitby jet is derived. It forms the zone of *Ammonites serpentinus*. The Ammonites found in

the Jet Rock frequently have their chambers filled with liquid bitumen.

The lowest division of the Upper Lias is the Grey Shale, which may be seen in the cliffs between Robin Hood's Bay and Whitby. The characteristic Ammonite is *A. annulatus*.

The Middle Lias may be divided into two parts—the Ironstone Series at the top, and Sandy Series underneath. They appear in the cliffs round the North Cheek of Robin Hood's Bay. The Ironstone Series consists of shale, with thin bands of ironstone, which are extensively worked in the Cleveland district. The sandstones of the Sandy Series are also very ferruginous, but not sufficiently so to be worked with profit. A peculiar feature of these beds is the occurrence of fossils in nests or small heaps—*Pecten cygnipes*, *Cardium truncatum*, and *Gryphea cymbium* being particularly abundant. Many of the fossils of the Sandy Series occur as pyritous casts, but are usually difficult to extract, the sandstones being so hard as to strike fire from the hammer.

The Lower Lias is well developed in Robin Hood's Bay; but the section is not quite complete, as the lowest zone—that of *Ammonites planorbis*—is not seen in the cliffs. Blocks of sandstone belonging to this horizon are, however, sometimes washed up by the tide, and from these the characteristic fossils may be gathered in plenty. The total thickness of the Lower Lias as here displayed is about 350 feet. It consists of soft shales containing many doggers, and with a few sandy and ferruginous bands. An interesting point is the occurrence, near the middle of the series, of a band of ironstone shewing cone-in-cone structure. Doggers, similar to those of the Lower Calcareous Grit, and Inferior Oolite are found plentifully throughout the Lias, and are frequently septariated. In a specimen exhibited the septaria were composed of calcite and blende.

All along the Yorkshire coast we find striking evidence of the rapidity with which the cliffs are being worn back by the action of the sea. Huge blocks of sandstone and shale, which have fallen from the face of the cliffs, lie strewn about in wildest confusion. The most rapid recession, of course, goes on at those localities where the cliffs are mainly or entirely composed of Boulder Clay—such as Filey, Redcar, and along the Holderness coast. Immediately in front of Filey Spa an embankment has been constructed to protect the houses close to the shore. At Holderness, south of Flamborough Head, the rate of denudation has been calculated at between two and three yards per annum—this along 36 miles of coast being equal to about 30 acres per annum. The Lias of Whitby and district is also being rapidly worn away. Between Robin Hood's Bay and Whitby masses of clay and shale are continually falling down, making the study of the coast sections attended with a slight amount of risk. Many years ago a landslip occurred at Robin Hood's Bay, when one side of an entire street slipped down on to the shore and was washed away. Ramsay also records a notable landslip, which took place a few years ago at Rosedale, on the North Horn of Runswick Bay, when a set of iron works, offices and cottages, together with a pier and harbour, were carried away to sea at night.

Liverpool Geological Association.

ANNUAL MEETING,

Held at the Free Library, Monday, 5th October, 1891, the President, Mr. D. Clague, F.G.S., *in the Chair.*

Election.—Mr. Thomas D. Roberts, of Handfield Place, was elected to membership.

In the course of an interesting *resumé* of the work done during the past Session, the President touched lightly on the several Papers read, and congratulated the members on the scope and value of these.

The Annual Report of the Council and the Financial Statement of the Treasurer—both appended—were read, and, on the motion of the President, unanimously adopted.

The following

OFFICERS AND COUNCIL

For the Year 1891-92

were then elected by ballot:—

President:
Mr. D. Clague, F.G.S.

Vice-President:
Mr. T. R. Connell.

Treasurer:
Mr. W. H. Miles.

Secretary:
Mr. James Paterson.

Council:
Mr. A. Norman Tate, F.G.S., &c.
Mr. C. E. Miles.
Mr. R. Storey.
Mr. C. F. Webb, L.D.S.
Rev. S. Gasking, B.A., F.G.S.

Annual Report, 1890-1.

At the close of another year your Council have to report that during the twelve months there have been 9 elections and 14 resignations, while 4 members have been removed under Rule 2, leaving the number on the roll at 84, viz., 6 honorary and 78 ordinary members.

Ordinary meetings have been held regularly every month, at which the following papers were read and discussed:—

"Scope of Geological Study," by the President, Mr. D. Clague, F.G.S.

"The Relations of Geology to Agriculture," by Mr. W. Scott Walker.

"Shore Fauna," by Mr. James Hornell.

"Work of a River," by Mrs. Scott.

"Economic Geology of Caithness," by Mr. G. Herbert Jones.

"Geology of Castleton, Derbyshire," by Dr. Cecil Webb.

"Diamond," by Mr. Joseph Davies.

"Work in the Boulder Clay near Bootle," by Mr. A. R. Pritchard.

"The Cliff Sections of the Yorkshire Coast," by Mr. R. W. B. Roberts.

At the January meeting a Soiree was held, when, by the kind permission of the Library and Arts Committee, the Free Library and Museum were opened to us in a special manner; and our thanks are due to the officials for their courtesy and attention on the occasion. The evening terminated with a concert of vocal and instrumental music.

Field Meetings have also been held during the year at the following places:—

Easter Monday, March 30.—Flaybrick and Bidston, under the guidance of Dr. Ricketts, F.G.S.

Whit Monday, May 18.—Matlock Bath, under the guidance of the President.

Saturday, June 20.—Dawpool, under the guidance of Mr. C. E. Miles.

Bank Holiday, August 3.—Colwyn Bay and Llandudno, under the guidance of Mr. Robert Storey.

On each occasion useful work being done. To the gentlemen who gave their services as conductors your warm thanks are due.

After some delay and irregularity at the commencement of the year your Council appointed a Publishing Committee, with the result that this department now works smoothly, and the Journal issued with sufficient punctuality to make it of real value to members.

The bound volume of Transactions for the previous year has been forwarded to the various learned societies with whom we exchange.

The Librarian reports the Library to be in good condition and of great use to members, but he states that there is a large and growing number of exchanges from other societies which would be more useful if bound. We have hopes that our funds will soon allow of this work being accomplished. The Library has been further enriched by donations from authors. Our thanks are specially due to Mr. G. H. Morton, F.G.S., for a copy of his recently issued work on the "Geology of Liverpool and District."

The Treasurer's Report, duly audited, is appended. On assuming office your Council had to labour under the incubus of a debt, accumulated in previous years, which crippled them in their efforts to advance the work of the Society; they

therefore resolved to make a special appeal to members for funds to liquidate the amount, and, happily, sufficient assistance has been rendered to secure the desired end.

Members are urged to send in their subscriptions promptly. Much labour and anxiety would be saved to the financial officer of the Society if this were done. *Bis dat qui cito dat.*

Your Council would also direct attention to Rule 12, which states that "Every member may introduce a friend at an ordinary meeting or field meeting of the Association," as it is essential to the well-being of the Society that new members be introduced to fill the places of those who resign from various causes.

LIVERPOOL GEOLOGICAL ASSOCIATION, in Account with the Treasurer,

FOR THE YEAR ENDING SEPTEMBER, 1891.

Dr. Disbursements.	£ s. d.	£ s. d.
To Printing and Stationery, to Sept., 1890	5 11 6	
,, Ditto, to Sept., 1891	15 19 6	21 11 0
,, Postages and Incidentals, to Sept., 1890	0 12 4	
,, Ditto, to Sept., 1891	4 8 6	5 0 10
,, Rent of Room, in settlement to Sept., 1891		2 15 0
,, Gratuity to Attendant		0 10 0
,, Balance in hands of Treasurer		1 16 10
		£31 13 8

Receipts. *Cr.*	£ s. d.
By Balance from last year	0 19 8
,, Subscriptions—	
1 for year 1888-89	
11 ,, 1889-90	
57 ,, 1890-91	
2 ,, 1891-92 (in advance)	
71 Subscriptions at 5s	17 15 0
,, Donations to Printing Fund	0 10 0
,, Receipts from Authors for Printing	2 11 0
,, Profit from Soiree	1 3 0
,, Special Donations	8 15 0
	£31 13 8
By Balance	£1 16 10
LIBRARY FUND.	
By Balance as per last account	0 11 6
	£2 8 4

Audited and found correct,

R. W. B. ROBERTS.
A. R. PRITCHARD.

W. H. MILES,
HON. TREASURER.

LIST OF KINDRED SOCIETIES, &c.,

to which copies of the Journal have been sent during the past year.

Exchanges have been received from those marked *.

*Australian Museum (Trustees of), Sydney.
*Australian Geological Society, Melbourne.
*Belfast Naturalists' Field Club.
Birmingham Natural History and Microscopical Society.
Bristol Naturalist Society.
British Museum, Natural History Department.
*Burnley Literary and Philosophical Society.
California State Mining Bureau, San Francisco.
Canada Geological and Natural History Survey, Ottawa.
*Chester Society of Natural Science.
*Cornwall Royal Geological Society, Penzance.
Cornwall Mining Association and Institute.
*Cotteswold Naturalists' Field Club.
*Cumberland and Westmoreland Association.
*Edinburgh Geological Society.
*Elisha Mitchell Scientific Society, N. Carolina.
*Falmouth Naturalist Society.
*Glasgow Geological Society.
*Geological Society, London.
*Hull Geological Society.
*Isle of Man Natural History Society.
*Lancashire and Cheshire Entomological Society.
*Leeds Geological Society.
Liverpool Architectural Society.
*Liverpool Astronomical Society.
Liverpool Biological Society.
*Liverpool Literary and Philosophical Society.
Liverpool Engineering Society.

*Liverpool Geological Society.
*Liverpool Microscopical Society.
*Liverpool Naturalists' Field Club.
Liverpool Philomathic Society.
Liverpool Polytechnic Society.
*Liverpool Science Students' Association.
Liverpool University College.
*London Geological Association.
*London Amateur Scientific Society.
*Manchester Geological Society.
*Manchester Microscopical Society.
*Manchester Scientific Students' Association.
**Midland Naturalist*, Birmingham.
North of England Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne.
Norwich Geological Society.
*Nottingham Naturalists' Society.
Nova Scotia Institute of Natural Science.
*Rochdale Literary and Scientific Society.
*Smithsonian Institution, Washington.
*United States Geological Survey, Washington.
*Victoria Department of Mines, &c., Melbourne.
Wagner Free Institute of Science, Philadelphia.
Yorkshire Philosophical Society, York.
*Yorkshire Geological Society, Halifax.
The Free Libraries of Barrow-in-Furness, Birkenhead, Birmingham, Bootle, Chester, Liverpool, Nottingham, Southport, St. Helens, and Warrington.



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